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A Comparison of Fire-Weather Severity in Northern Alberta During the 1980 and 1981 Fire Seasons

by

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Abstract

The burning potential of two major fire seasons in northern Alberta is evaluated with the use of the Canadian Forest Fire Danger Rating System (CFFDRS). Fire danger class frequency and severity ratings based on the Fire Weather Index (FWI) component in the CFFDRS were utilized in the evaluation. Daily fire-danger reports from 16 selected fire weather stations distributed throughout the northern half of the province provided the basis for the analysis. Although the Seasonal Severity Rating (SSR) for 1981 was slightly higher (SSR = 3.1) than that of 1980 (SSR = 2.5), the area burned in 1981 was about double that of the previous year. The period of critical fire weather began early in the 1980 fire season and prior to the normal summer lightning pattern, whereas in 1981 it occurred during the latter half of the fire season and coincided with the majority of the lightning incidence. FWI severity ratings were not designed to portray a complete picture of the total potential fire containment job but rather to provide an objective basis on which to compare the severity of one season's fire weather with another.

Key words: Fire Weather Index, fire season severity rating, critical fire weather, lightning occurrence, northern Alberta.

Résumé

Le potentiel de brûlage de deux saisons de feux majeures dans le nord de l'Alberta est évalué à l'aide de la Méthode Canadienne d'Evaluation des Dangers d'Incendie de Forêt (MCEDIF). La fréquence des classes de danger de feu et les évaluations de la sévérité basées sur la composante Indice Forêt-Météo (IFM) de la MCEDIF ont été utilisées dans l'évaluation. L'analyse est basée sur des rapports quotidiens de danger de feu provenant de 16 stations météorologiques forestières distribuées à travers la moitié nord de la province. Même si l'Evaluation de la Sévérité Saisonnière (ESS) pour l'année 1981 s'est avérée légèrement supérieure (ESS = 3,1) à celle de 1980 (ESS = 2,5), la surface brûlée en 1981 a été environ le double de celle de l'année précédente. La période de météorologie forestière critique a commencé tôt durant la saison des feux de 1980, avant-même la période normale des orages électriques de l'été, tandis qu'en 1981 elle s'est produite lors de la deuxième moitié de la saison des feux, coïncidant avec la majorité des orages électriques. Les évaluations de la sévérité basées sur l'IFM n'ont pas été conçues afin de représenter une image globale du travail potentiel total nécessaire afin de contenir le feu mais plutôt afin de fournir une base objective servant à comparer les saisons de feux en terme de sévérité.

Mots clés : Indice Forêt-Météo, évaluation de la sévérité de la saison des feux, météorologie forestière critique, foudre, nord de l'Alberta.

Introduction

Early in 1981, the previous fire season (1980) in much of west-central Canada was termed the worst in recent memory (Stocks *et al.* 1981, Harrington 1981, Stocks 1983). However, during the 1981 fire season, more area was burned and suppression expenditures were higher in Alberta than in the previous year (Table 1). Total area burned in Alberta during 1981 almost exceeded 1.4 million hectares compared with about 0.7 million hectares in 1980. The common factor in both fire seasons was a prolonged period of very warm, dry weather in the northern portion of the province. How do the two years compare in terms of fire-weather severity? Was 1981 worse than 1980? How did the normal ignition agents (i.e., lightning and people) fit into the picture? This paper attempts to answer these and other questions for northern Alberta (defined as essentially the area north of latitude 54° N) where most of the fire control problems occurred in both years (Gray and Janz 1985, Delisle and Hall 1987).

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Table 1. Forest fire statistics for Alberta (excluding National Parks) during the 1980 and 1981 seasons[1]

Item	Fire season 1980	1981
Total number of fires	1 348	1 522
% caused by lightning	45.2	55.5
Total area burned (MM ha)	0.67	1.37
% due to lightning fires	44.6	99.6
Average fire size (ha)	499	897
Lightning fire	492	1 612
Man-caused fire	504	8
Number of 'Class E' fires[2]	42	28
% caused by lightning	61.9	78.6
Area burned by 'Class E' fires (MM ha)	0.63	1.31
% due to lightning fires	40.3	99.8
Fire-fighting costs (MM $)[3]	26.8	51.8

[1]Basic data extracted from Anon. (1983a, 1983b).
[2]Greater than 200 hectares in size.
[3]Includes only variable costs (i.e., suppression expenditures). Fixed costs amounted to $16.4 and $22.2 million in 1980 and 1981, respectively.

Review and Methods

The severity of the weather in relation to two or more fire seasons can be assessed in several ways (e.g., Turner 1970). The best means of quantitatively comparing the fire-weather severity for two or more years is to use a cumulative daily index of fire danger computed or obtained from basic weather observations collected at representative fire weather network stations (e.g., Williams 1959, Nelson 1961, Countryman and Pirsko 1962, Barney 1964, Dieterich and Brown 1964, Nikleva 1973, Murphy 1985).

The Canadian Forest Fire Weather Index (FWI) System (Canadian Forestry Service 1984, Van Wagner and Pickett 1985, Van Wagner 1987) was adopted in 1971 as the standard for fire danger rating in Alberta as it was elsewhere in Canada. Since its introduction in Alberta, the system has been used with growing confidence as a decision aid in a variety of fire management planning and operational activities (Kiil *et al.* 1986). The FWI System consists of six components which are calculated on the basis of consecutive noon local standard time observations of dry-bulb temperature, relative humidity, wind speed, and 24-h accumulated precipitation. The Fire Weather Index (FWI) component of the system is a numerical rating of frontal fire intensity or flame length in a standard fuel type (i.e., jack or lodgepole pine forest) (Van Wagner 1987) and is used as a general fire danger index. The FWI scale is "open-ended". However, the occurrence of values over 100 is fairly rare. The familiar adjective or descriptive 'fire danger class' (i.e., Nil or Very Low, Low, Moderate, etc.) (Canadian Committee on Forest Fire Management 1987) is determined by the FWI value.

Williams (1959) devised a method of rating fire season severity that relied on the 1956 edition of the fire danger index used in Canada. Van Wagner (1970) subsequently converted Williams' "severity rating" factors for use with the FWI.

The methods of analyzing fire-weather severity that have been adopted in the present study are as follows:

1. Computation of severity ratings based on the FWI component of the FWI System as described by Van Wagner (1970) and illustrated in Figure 1.
2. The percentage of days with fire-danger ratings above a specified critical value. In Alberta, the threshold level for a "Very High" fire danger class is an FWI ≥ 19 (Kiil *et al.* 1977).

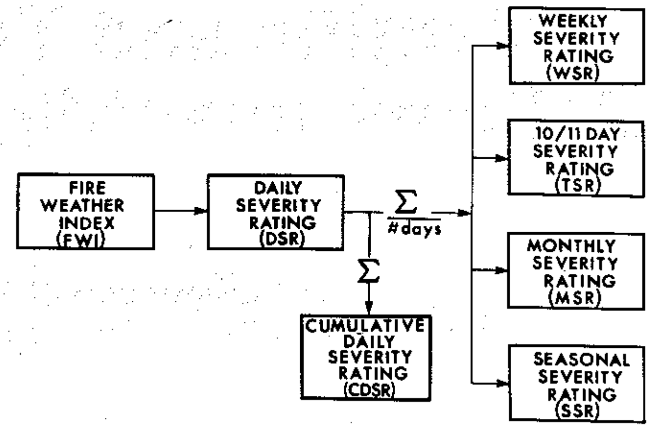

Figure 1. Flow chart of severity associated with the Canadian Forest Fire Weather Index System.

The latter approach simply indicates the number of days in the fire season rated as 'Very High' and 'Extreme'. Thus, it gives an idea of the proportion of time during which a certain state of preparedness for new fire starts must be maintained. There is, however, no differentiation between index values just above the threshold and those that are significantly larger. For instance, an FWI of 20 is treated the same as a value of 90. The experienced fire manager knows that a single day with an FWI of 90 can be vastly more disastrous in terms of area burned than a week with an FWI of 20. Statistics for 1981 in northern Alberta suggest that although many fire starts due to lightning occurred with FWI values in the 'High' and 'Very High' classes, the majority of the area burned over a relatively few days when FWI values exceeded 50.

The intent of FWI severity rating analyses is to allow an objective comparison to be made, strictly in terms of the influence of fire weather on potential fire behavior, of one fire season against another or one station, area, etc. against another (e.g., Stocks *et al.* 1981, Anon. 1983c). It has also been used to compare monthly or yearly severity ratings in relation to various measures of 'fire business' such as area burned or fire incidence (e.g., Shortt 1982, Harrington et al. 1983, Murphy 1985) and in developing area fire danger climatologies (e.g., Stocks 1971, 1978). Recently FWI severity rating, in conjunction with fire occurrence data, was applied to the task of rationalizing a proposed annual level of fire suppression funding[4].

The Daily Severity Rating (DSR) for each day is calculated from the FWI based on the formula given by Van Wagner (1970, 1987):

[1] $DSR = 0.0272\ (FWI)^{1.77}$

The daily values of the FWI cannot be simply accumulated to determine fire season severity without proper weighting. The DSR, being a simple power function of the FWI (Fig. 2), gives greater weight to higher values than lower ones. Daily values of the DSR can be summed to obtain a cumulative value and averaged over any desired period such as a week, month or season. For example, the New Brunswick Department of Natural Resources reports its severity ratings on a weekly basis during the fire season in their monthly *Fire Protection Newsletter*.

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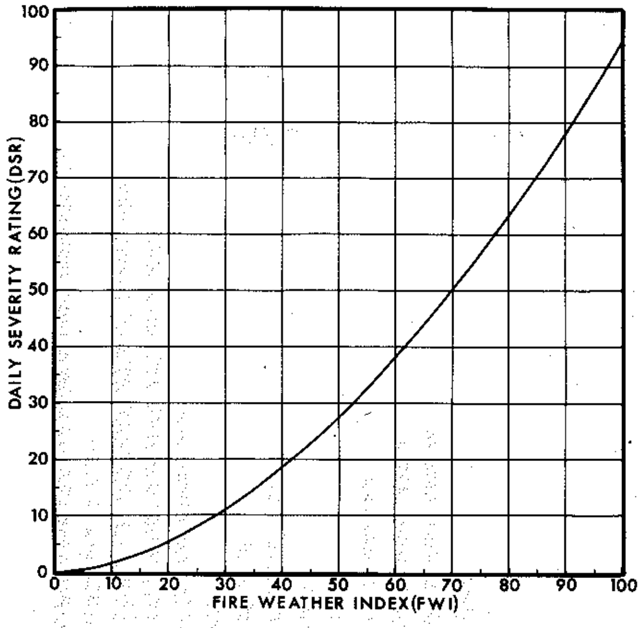

Figure 2. Relationship between Daily Severity Rating and the Fire Weather Index according to Van Wagner (1970).

Both Van Wagner (1970) and Drysdale (1976) have prepared tabulations of DSR versus FWI values for daily operational use involving manual computations; a third version is available upon request from the second author of this paper. Computer calculation is of course also possible (Van Wagner and Pickett 1985).

The Weekly Severity Rating (WSR), Ten-day[5] Severity Rating (TSR), Monthly Severity Rating (MSR), and Seasonal Severity Rating (SSR) are calculated as follows (after Van Wagner 1970):

$$[2]\ WSR = \frac{\Sigma\ DSR}{7}$$

$$[3]\ TSR = \frac{\Sigma\ DSR}{10 \text{ or } 11}$$

$$[4]\ MSR = \frac{\Sigma\ DSR}{n}$$

$$[5]\ SSR = \frac{\Sigma\ DSR}{N}$$

where, Σ DSR = summation of the DSR values for the time interval specified (i.e., week, 10- or 11-days, month, or season), n = actual number of days in the month and N = total number of days in the fire season. Any severity rating over about 2.0, especially averaged over a month, represents weather conditions favorable for extensive burning (Stocks *et al.* 1981).

The FWI values reported from 16 selected lookout fire weather stations (Fig. 3) operated by the Alberta Forest Service (AFS) were tabulated for the period April 21 to September 20 during both fire seasons (N = 153). The FWI values were converted to DSRs using Equation [1]. The TSRs for 15 time periods were calculated for each station using Equation [3]. These were then averaged for northern Alberta as a whole, and bar graphs prepared as illustrated by Stocks and Street (1983). Cumulative DSR (CDSR) curves were derived, by multiplying each TSR by 10 or 11 as appropriate and then sequentially summing the resulting computations, in order to display the chronological development of the two fire seasons. Alternatively, the individual DSRs could be simply summed (i.e., CDSR = Σ DSR up to a given date). MSRs and SSRs for each station were determined by Equations [4] and [5] and then averaged for northern Alberta.

[5]Eleven days for the third period in a month with 31 days.

To assess the timing of lightning occurrences in relation to fire-weather severity during the two fire seasons, the percentage of lightning days and days with FWI values ≥ 19 were tabulated by 10-day periods and the results jointly graphed for comparative purposes. The occurrence percentages represent the average frequency based on all 16 stations. Information on lightning incidence for each station was determined on the basis of the AFS administrative 'Forest' (see Fig. 3) in which it was located.

Results

The average TSRs for northern Alberta during the 1980 and 1981 fire seasons are shown in Figure 4. A quick glance at the graph might easily lead the reader to conclude that perhaps 1980 was more severe than 1981. Three periods in 1980 (i.e., April 20 to May 19) certainly tend to overshadow the rest of the fire season. However, the worst of the 1980 fire

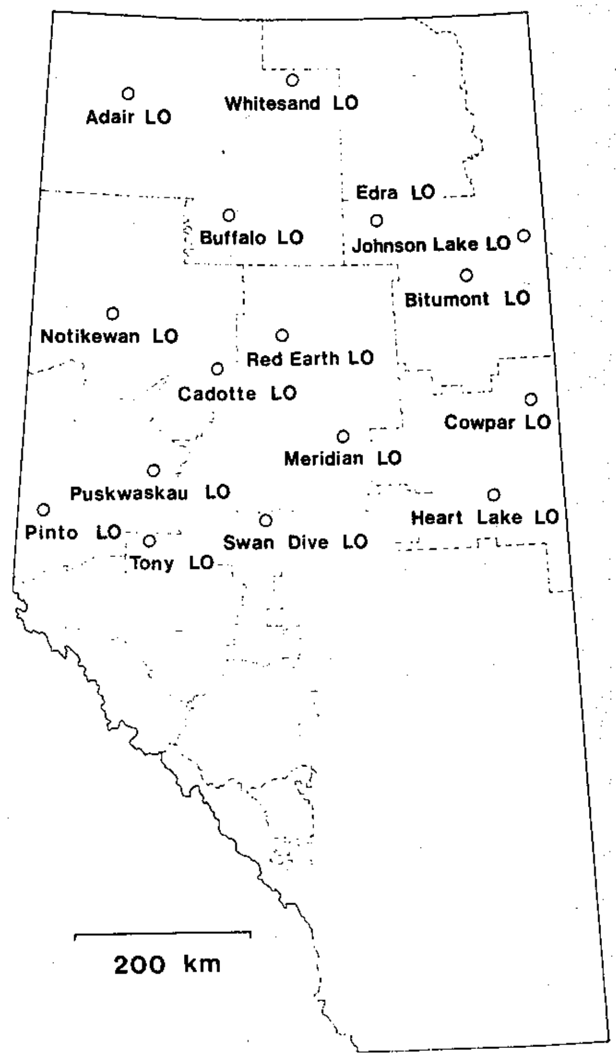

Figure 3. Location of the 16 Alberta Forest Service (AFS) lookout (LO) fire weather stations used in the present study. The boundaries of the ten administrative 'Forests' of AFS and the three largest National Parks in Alberta are denoted by dashed lines.

season was over by May 20 and although burning conditions remained favorable during June, the season was fairly quiet thereafter. During the 1980 fire season there were *six* times when the TSR exceeded a value of 2.0. The 1981 fire season began with a moderate amount of wildfire activity in May and early June, followed by a relatively quiet interval until July 10-19, when there was another active fire period (Fig. 4). However, the most significant period of major fire activity was from the beginning of August until the middle of September. The 1981 season had *nine* periods with TSR values greater than 2.0. As will be shown subsequently, a noteworthy statistic about the 1981 fire season is that in terms of the average TSR for northern Alberta, mid-September was by far the worst. According to the modern fire record in Alberta, it is very unusual to experience nearly three continuous weeks of severe burning conditions in the fall.

CDSR curves, show at any given time during the fire season the level of fire-weather severity reached up to that date. The CDSR curves for the 1980 and 1981 fire seasons, indicate that the cumulative severity of the 1981 season did not exceed that of 1980 until early September (Fig. 5). Note the steep inclines in the curves April 20 and May 20, 1980 and after August 1, 1981.

The MSRs and SSRs for individual stations and for northern Alberta as a whole for both fire seasons are given in Table 2. In 1980, there were 36 "station months" out of 96 with MSRs $\geq$ 2.0 compared with 52 in 1981. The SSRs of 2.5 and 3.1 for 1980 and 1981, respectively, indicate that both seasons were severe fire weather years. Eight of the 16 stations had SSRs $\geq$ 2.0 in 1980, compared with 14 in 1981. It is clear from Fig. 4 and Table 2 that the two seasons were vastly different in the timing of critical fire weather. In 1980, it occurred exceptionally early in the fire season, whereas in 1981 it began in late summer and continued through early fall (Alexander *et al.* 1983, Nimchuk 1983, Gray and Janz 1985, Street and Birch 1986).

The frequency of lightning incidence and FWI values $\geq$ 19 by 10-day periods for the 1980 and 1981 fire seasons are shown in Fig. 6. The two fire seasons were clearly quite different in occurrence of the high frequency of lightning relative to the timing of critical fire weather. During periods having a high percentage of days with FWI values $\geq$ 19 coupled with a low lightning frequency, the probability of lightning fire ignitions was greatly reduced (e.g., early May 1980). On the other hand, during periods having a high frequency of lightning occurrence and FWI values $\geq$ 19, the probability of ignition was in turn greatly enhanced (e.g., August 11-20, 1981).

Discussion

The FWI is intended to represent the energy output rate of a single spreading fire per unit length of the active flaming front (Van Wagner 1987). Thus, the FWI, and consequently the DSR, TSR, MSR, and SSR which depend directly on it, is effectively a measure of potential fire intensity *provided* there is a source of ignition. There is nothing inherent in the FWI relating to the presence or activity level of fire-starting agents, in other words, ignition risk. (However, the fuel moisture codes associated with the FWI are in fact related to the ease of ignition.) This statement is reflected in the ignition patterns of the 1980 and 1981 fire seasons which were quite different. In 1980 the most critical fire weather occurred *before* the active lightning season. In fact, except for a few lightning fires in mid-May, the majority of large, problem fires in 1980 were man-

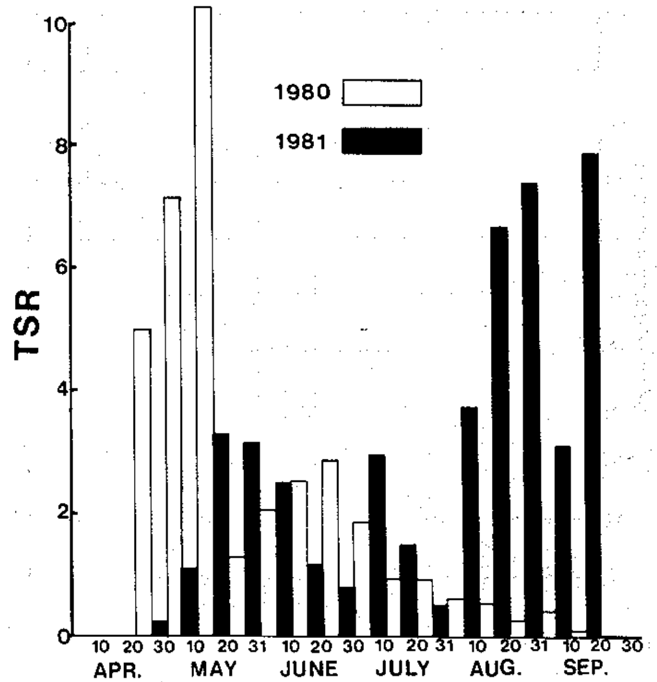

Figure 4. The Ten-day Daily Severity Rating (TSR) values for northern Alberta during the 1980 and 1981 fire seasons.

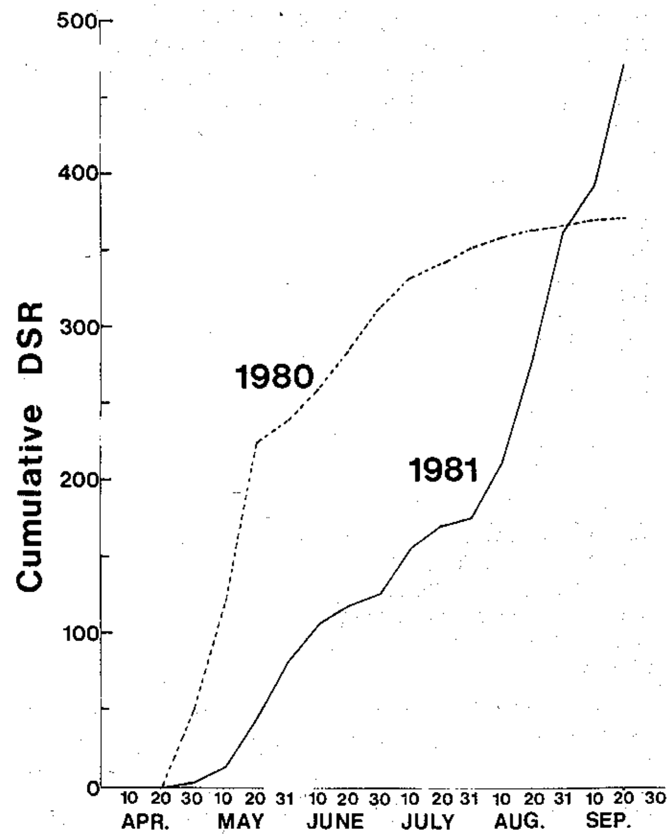

Figure 5. The cumulative Daily Severity Rating (DSR) curves for northern Alberta during the 1980 and 1981 fire seasons.

caused (Delisle and Hall 1987) and accounted for more than half of the area burned in that year (Table 1). In 1981 the reverse was true. The most critical fire weather occurred *during* and *following* the active lightning period and virtually all the major wildfires were the result of lightning (Delisle and Hall 1987).

Table 2. Monthly Severity Ratings (MSR) and Seasonal Severity Ratings (SSR) for 16 selected lookout (LO) fire weather stations in northern Alberta during the 1980 and 1981 fire seasons.

Fire weather station		1980							1981						
Name	Elevation (m MSL)	MSR							MSR						
		Apr.[1]	May	June	July	Aug.	Sep.[2]	SSR	Apr.[1]	May	June	July	Aug.	Sep.[2]	SSR
Whitesand LO	962	0.5	3.6	3.1	1.7	1.0	0.7	2.0	0.0	0.9	2.1	1.9	5.6	5.1	2.8
Buffalo LO	800	2.0	3.6	1.2	0.4	0.4	0.2	1.3	0.0	2.3	2.6	1.9	7.6	5.0	3.5
Adair LO	396	2.7	5.9	4.6	2.0	2.3	1.0	3.3	0.0	4.2	2.9	2.2	4.4	2.7	3.1
Notikewan LO	937	2.2	4.2	1.1	0.6	0.3	0.2	1.4	0.0	1.0	1.3	1.1	5.0	5.1	2.4
Cadotte LO	733	0.9	3.2	1.7	1.5	0.7	0.2	1.5	0.0	3.8	2.7	2.3	10.5	7.0	4.7
Puskwaskau LO	907	2.8	5.5	0.6	0.7	0.3	0.2	1.7	0.3	2.0	1.4	2.6	8.8	5.1	3.7
Pinto LO	1 044	1.5	1.7	*[3]	0.4	0.2	0.1	0.6	0.1	0.5	0.8	2.1	4.6	4.7	2.2
Tony LO	1 006	3.1	5.8	0.4	1.1	0.2	0.2	1.8	1.0	1.2	0.3	0.9	2.9	4.5	1.7
Swan Dive LO	1 245	3.2	3.0	0.4	0.3	*[3]	*[3]	1.0	0.1	0.8	0.1	0.5	3.6	5.7	1.8
Red Earth LO	621	7.6	7.0	1.2	0.4	0.3	0.1	2.3	0.0	2.9	1.5	1.9	8.1	5.8	3.6
Meridian LO	937	10.7	5.2	2.1	0.2	0.1	*[3]	2.2	0.4	2.6	0.3	0.6	5.5	5.3	2.5
Edra LO	802	1.7	3.1	3.5	1.4	0.8	0.1	1.9	0.0	1.5	1.5	1.5	6.5	8.4	3.2
Bitumont LO	365	14.5	22.3[4]	12.6	6.1	0.5	*[3]	9.4	0.1	4.1	2.4	3.1	9.7	8.7	5.0
Johnson Lake LO	582	4.9	5.5	3.8	1.8	0.2	0.1	2.6	0.0	3.5	1.6	1.5	3.3	5.4	2.7
Cowpar LO	552	14.4	10.3	1.9	1.2	0.4	0.2	3.8	0.5	4.6	1.1	0.9	6.7	6.8	3.6
Heart Lake LO	863	7.1	7.9	1.8	0.6	0.1	0.5	2.7	1.2	5.0	1.4	1.1	3.2	3.2	2.6
Northern Alberta	-	5.0	6.1	2.5	1.3	0.5	0.2	2.5	0.2	2.5	1.5	1.6	6.0	5.5	3.1

[1]Includes only the period Apr. 21-30.
[2]Includes only the period Sep. 1-20.
[3]Value less than 0.05.
[4]An FWI of 126 was reported on May 20.

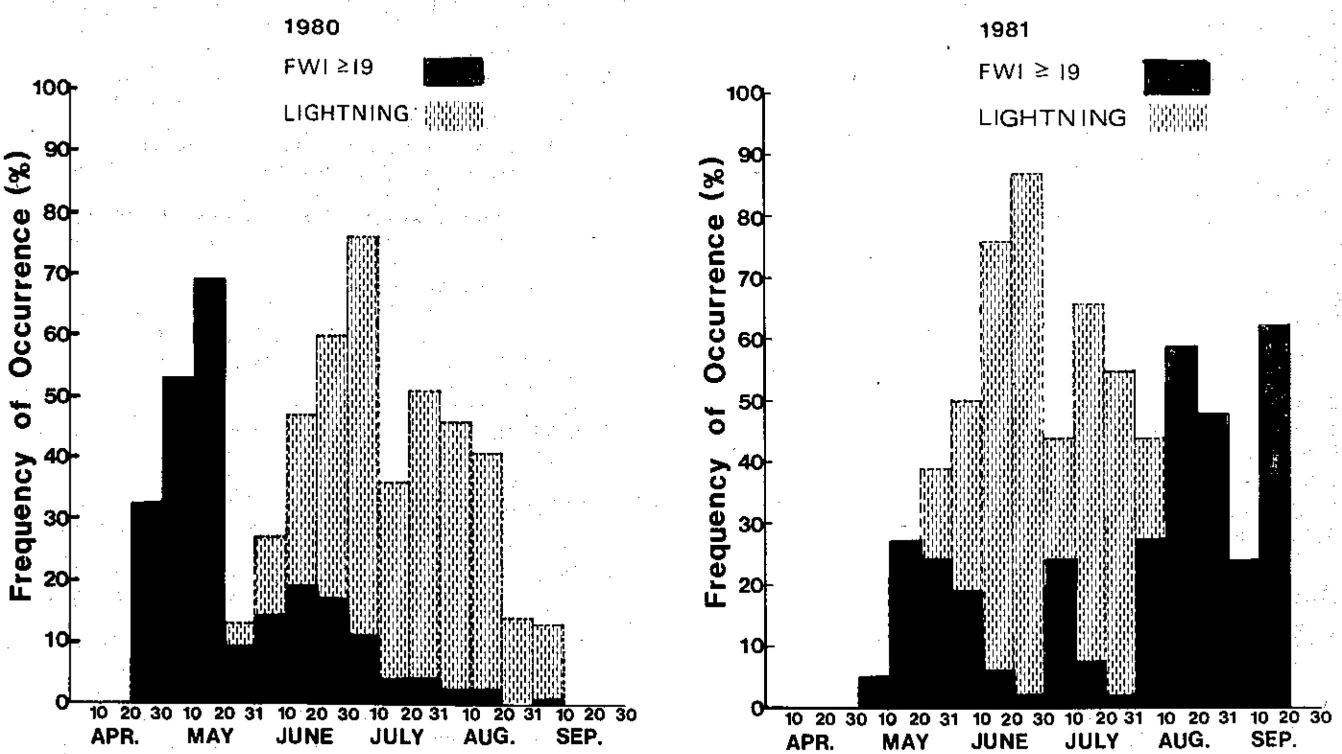

Figure 6. Frequency of Fire Weather Index (FWI) values ≥ 19 and lightning occurrence by 10- or 11-day periods in northern Alberta during 1980 and 1981 fire seasons.

In retrospect, it would appear that the most ominous period in 1981 occurred between August 11-20. Although this was not the period with the greatest area burned, it was the period during which six lightning fires started, each of which eventually exceeded 100 000 hectares in size. With the exception of the Swan Hills Fire (DS3-23-81), these fires were still burning on August 27. This day will go down in the Alberta record books as 'Black Thursday'. Approximately 325 000 hectares, or about 25% of the total area burned in Alberta during 1981, was burned over during a 10 to 12-hour period on August 27 (Nimchuk 1983).

Conceptually, the two fire seasons could be thought of as being similar in that most of the lightning incidence did not coincide with the critical fire weather pattern, except for one 10-day period in 1981 (i.e., August 11-20). However, the analyses in this paper clearly show that the two fire seasons were considerably different in the timing of critical fire weather. The most devastating portion of the 1980 fire season was over by the third week of May whereas the most disastrous part of the 1981 season did not begin until August. The question now arises whether the same two patterns could occur in one fire season. There is nothing inherent in the physics of the atmosphere to preclude such an event. In other words, it is possible to have a severe fire season with a beginning like that of 1980 and an ending like that of 1981. However, historical records suggest that the likelihood of such a combination is rather remote.

The four severity ratings incorporate all the features of the FWI, namely the influence of past and current weather, especially rain, on the degree of forest flammability. Thus, the DSR, TSR, MSR, and SSR represent objective yardsticks to gauge the effects of fire weather on potential fire behavior. However, the 1980 and 1981 experience in Alberta suggests that they are only qualitative indicators of fire season severity in the conventional sense. Politicians, the general public, and often land managers measure the severity of a fire season in such terms as area burned, number of fires, pattern of fire occurrence, volume of merchantable timber lost, suppression expenditures, frequency of community evacuations, and so on. Consider the fact that in 1980, with an SSR of 2.5, the area burned was 0.67 million hectares (1.5% of northern Alberta) and the suppression costs reached close to $27 million (Table 1). Yet in 1981, with an SSR of 3.1, the area burned was 1.37 million hectares or slightly more than double (3.1% of northern Alberta) and the direct fire fighting costs escalated to nearly $52 million. Fire control costs are a reflection of fire management policy to a large degree and thus are not directly considered in the severity rating calculations.

The DSR was designed to represent a numerical measure of the effort to suppress a single forest fire. It does not, however, completely account for *fire load* which is "the number and magnitude . . . of all fires requiring suppression action during a given period within a specified area" (Canadian Committee on Firest Fire Management 1987). Fire load is usually a function of incidence, size, and intensity (e.g., Turner 1973, Murphy 1985, Canadian Committee on Forest Fire Management 1987) — which depends on fire-weather severity, ignition patterns, and fire control efficiency. The severity ratings derived from the FWI only represent an independent measure of fire-weather severity. Thus, the daily, weekly, monthly and seasonal ratings should not be used as the sole measure of the total suppression effort required to contain all fires.

Summary and Conclusions

1. Both 1980 and 1981 were severe fire weather seasons in northern Alberta. The Seasonal Severity Rating for 1981 was only slgihtly higher than that of 1980. Thus, the *potential* for burning on the basis of weather conditions alone was roughly equal during the two fire seasons.

2. The two seasons were considerably different in the distribution of extreme burning conditions. During the 1980 season, the critical fire weather occurred exceptionally early in spring, whereas in 1981 it lasted from mid-August until late September.

3. The other major difference between the two fire seasons is related to the timing and nature of the ignition agents in relation to burning conditions. In 1980 critical fire weather occurred *before* the active lightning season and nearly all the problem fires were man-caused. In 1981 favorable conditions for burning occurred at the end and primarily *after* the active lightning portion of the fire season. Thus, there were a number of ongoing lightning fires that persisted into the critical fire weather periods of late August and September. Several of these fires accounted for most of the area burned during 1981.

4. FWI severity ratings cannot, by their very nature, be expected to be completely indicative of the total effort or work required to contain all fires within a protection unit during a particular time. They are useful tools in research and administration for objectively analyzing the influence of fire weather conditions on potential fire behavior.

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